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Viewpoint

Computer vision technology for real-time food quality assurance during drying process

Mortaza Aghbashlo[a,*], Soleiman Hosseinpour[a] and Mahdi Ghasemi-Varnamkhasti[b]

[a]Department of Agricultural Machinery Engineering, Faculty of Agricultural Engineering and Technology, University of Tehran, Karaj, Iran (Tel.: +98 261 2801011; fax: +98 261 2808138; e-mail: maghbashlo@ut.ac.ir)

[b]Department of Mechanical Engineering of Biosystems, Shahrekord University, Shahrekord, Iran

Drying process causes many changes in the mechanical, sensorial, and nutritional properties of food products. One main challenge in the production of dried food products with acceptable shape, size, color, and texture is to monitor and control their appearance in real-time manner. Currently, there is an increasing demand for real-time approaches such as computer vision technology to monitor and control the food quality indicators including shape, size, color, and texture during drying process. This note briefly describes the potential application of computer vision system in the monitoring and controlling of the food drying process in order to enhance the dried product quality and identifies prospects for future investigations.

Background

Drying process is an important and extensively used operation in food industry in order to prevent (or inhibit) the growth and activity of micro-organisms, to make it available throughout the year and at all locations, to extend the expected shelf life of product, and to reduce the weight and bulk of food for reducing the charges of transportation and storage (Aghbashlo, Mobli, Rafiee, & Madadlou, 2013). However, there will be a significant loss in the nutritional, functional, mechanical, and sensorial parameters of food products if the drying process is performed inappropriately. Additionally, the acceptability and marketability of dried food is greatly put through its uniformity in accordance with the structure, shape, size, color, texture, and flavor. Since the visual appearance and sensible aroma are the most important criteria in preferring a new product by consumers.

Traditionally, the quality of dried food are usually evaluated off-line by a number of quality parameters such as moisture content, structural shrinkage, surface color, rehydration ratio, chemical compositions, viscoelastic and mechanical properties, and internal microstructure on end-product samples. However, discrimination of failure cause and abatement of the process failure using these traditional off-line evaluations and subsequent empirical models are most difficult or even impossible. Therefore, it is of interest to apply advanced, *in situ*, real-time inspection tools, capable of in-process monitoring of the organoleptic, mechanical, and nutritional attributes using the indirect visual properties measurements during drying process. In other words, these characteristics must be precisely monitored and controlled not only for the products quality but also for a better understanding of the ill-defined drying process and complex underlying mechanisms. Furthermore, food drying process is a quite complex and dynamic phenomenon, whose undergoing mechanisms are not yet completely understood. It could be attributed to the simultaneous heat and mass transfer phenomena, case-hardening, surface cracking, and severe physiochemical and biological changes occurred during drying process. As well, drying process is susceptible to the environmental and random modifications as results of unsteady ambient conditions. These can lead to a great product quality loss with a large deviation in the organoleptic attributes of finished products. Hence, the conventional measurement techniques cannot be accurately applied for real-time monitoring and controlling of food drying process. This research field becomes even more important due to a trend today in food industry from batch processes towards continuous processes, in which the request for in-process quality feedback control

* Corresponding author.

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are increasing for producing the healthy dried foods. Furthermore, non-homogeneity, anisotropy, and non-uniformity of the biological materials hinder successful application of the previously developed empirical models for precise real-time monitoring and automation. Therefore, it is essential to measure the food quality parameters in an in-process successive manner to achieve the efficient drying process in food industry.

On the other hand, according to Quality by Design strategy (QbD), quality must be retained, protected, and even built-not examined-into the foodstuffs through processing units. A QbD development process may include several steps as clearly shown in Fig. 1.

Obviously, real-time measurement techniques have an important role in the QbD approach. These techniques are commonly non-destructive and fast and are divided into three categories i.e. in-line, on-line, and at-line, according to Food and Drug Administration (FDA, 2004). The differences between off-line, at-line, on-line, and in-line measurement approaches are manifested in Fig. 2. At-line process measurement is often performed by sampling from the process and analyzing in close vicinity to the process apparatus within the timescale of processing. In the on-line approach, the gathered sample from process stream is diverted to the measurement equipment via an automatic sampling device and is frequently returned to the process stream. In-line process measurement (invasive or non-invasive) is carried out without withdrawing sample from the process stream, by direct placing of the analyzers into the process stream (Burggraeve, Monteyne, Vervaet, Remon, & Beer, 2012). It can be concluded that the in-line and on-line approaches are less time-consuming and have a big potential for developing a feedback controller based on the monitoring of the organoleptic attributes.

Nowadays, real-time monitoring of food appearance by computer vision system has become a main issue in food industry, since it is consistent, efficient, and cost effective alternative over the off-line destructive methods. This approach is a rapid, safe, reliable, and non-destructive technique, which requires no sample withdrawing and can be

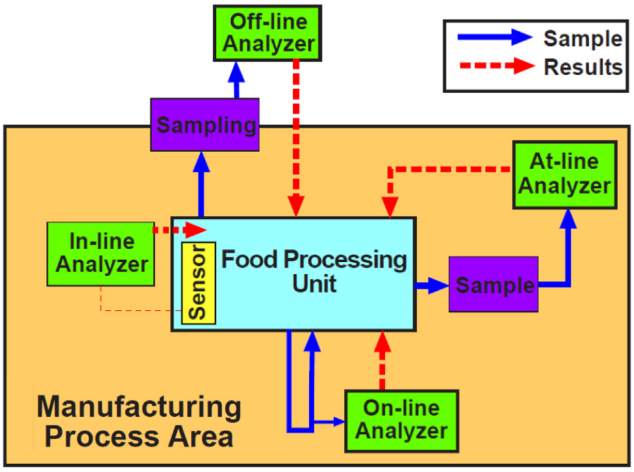

Fig. 2. An illustrative schematic for indicating the difference between off-line, at-line, on-line, and in-line measurement techniques.

applied as in-line, at-line, on-line and off-line measurement tools for the shape, size, color, and texture analyses in food processing operations. One key attribute that enables image processing suitable for qualitative measurements during food processing is the relationship between the product quality attributes and the appearance of foods including physical structure, color, and visual texture. Thus, a rapid image-based screening technique providing information regarding the organoleptic properties would be useful in food processing operations.

Fig. 3 manifests the analogy between the biological and artificial vision systems. Obviously, the computer vision system tries to mimic the processing and behavior of biological systems as much as possible.

In general, the main steps in computer vision technology can be divided into five steps as follows:

(1) Image acquisition to provide a digital image by one or several image sensors;
(2) Pre-processing including deblurring, image compression, re-sampling, noise reduction, contrast enhancement, and scale space representation to improve captured image;

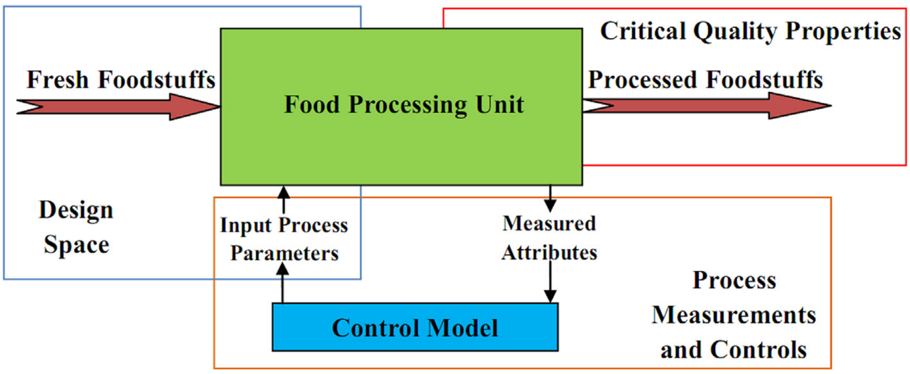

Fig. 1. QbD steps for food quality assurance.